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FIRE-FIGHTING WATER TURRET

Field of the invention

[0001] This invention relates to a fire-fighting turret or monitor, or similar fluid-projecting device, which is mounted in a fixed position but can be aimed in any direction and at any elevational angle by rotating a pair of swivelable joints disposed at an acute angle to each other.

Related cases

[0002] This application claims the benefit of provisional application Serial No. 60/213,016 filed 21 June 2000 and entitled "A New Design for Fire-fighting Water Turrets, or Monitors".

Background of the invention

[0003] In fire fighting and other applications, water turrets or monitors are used to direct a stream of water. Generally these monitors are controlled by a manual operator who maneuvers a handle or other mechanically linked device, or by an operator who remotely controls the action of the monitor through hydraulic or electric links or a combination thereof. Such monitors can also be operated and activated automatically, as for example by a fire detector or timed circuit.

[0004] It is desirable to make such turrets cover an area with a volume of water by appropriately moving the nozzle continuously or intermittently to aim the water stream in different directions. In

general, the positional variables of the monitor include the elevation and azimuth in which the nozzle is pointing or spraying. Thus terms like Left, Right, Up and Down are used to label the positional turret controls and describe the motion of the stream.

[0005] As the state of the art has evolved from handheld hoses and nozzles to the manually operated turrets, and on to the remotely controlled and automatic monitors discussed above, there has been a tendency to add onto current methods without going back to the primary function to be served and creating a product from the ground up. Thus the axes necessary to create independent left-right and up-down actions were maintained without change from the hose to the monitor to the remote-controlled monitor. In addition, each of the axes or joints could be held against unintended movement by a mechanical device such as a friction lock or a pin in a hole. Automating merely meant adding electrical, mechanical or hydraulic actuators to the joints and swivels that were used in the mechanically controlled units. To gain the torque necessary to control the joints and to supply the static friction required to hold the nozzle in place when not being moved in one of the axes, a combination of gears including a worm gear was generally used.

[0006] Several general models of monitors have been devised to create the ability to sweep through the necessary range. One of these is a re-converging stream in which the water generally passes through a pipe that swivels to create the left-right rotation and coverage, then splits roughly equally and directs the water through separate symmetric pipes into flows which are perpendicular to the first swivel. This allows for a second set of swivels to provide the

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up-down coverage. Then the water is re-converged into a single stream and sent through a nozzle as desired. This model requires several complex cast components. Splitting the water into two pipes, forcing it through a quick series of sharp bends, then recombining the two streams which are running in almost opposite directions creates turbulence, back pressure and pressure losses that are detrimental to the water flow.

[0007] Another model can be thought of as a series of bent tubes. In this traditional configuration the water stream is forced over 45° of bends, with one bend being a 180° bend causing the stream to flow twice as far and twice as fast on the outside of the bend as the water on the inside of the bend. This geometry also creates turbulence and pressure drops that are adverse to the final stream pattern.

[0008] A third model is a tighter version of the bent tube design created by using castings. This allows for a tighter geometry but exaggerates the turbulence of flow speed differentials. In order to combat these problems, this design is forced to increase the cross-sectional area of the joint areas, which increases turbulence and forces acting on the joints. Even internal flow straightening vanes cast into the waterways to combat these deficiencies have the adverse effect of causing additional surface drag.

[0009] When these designs were automated to allow for operator control through switches or a joystick, or to allow for automatic operation in a preset manner without input from an operator, gearing and actuators such as electric and hydraulic motors were added on top of existing designs.

Summary of the invention

[0010] The present invention overcomes the problems of the prior art by providing a monitor or turret using a single curved tube with three mutually rotatable sections. The sections are separated by two swivelable joints whose axes are at an acute angle (e.g. 45°) to each other. The axes of the joints are interdependent, i.e. rotation of one joint changes the axial or angular orientation of the other joint. By concurrently rotating both joints, the nozzle can be aimed at any point within more or less a hemisphere centered on the monitor.

[0011] In accordance with one aspect of the invention, the joints are preferably rotated by a direct electric or hydraulic drive or servo motor in which the static position of the monitor is maintained electrodynamically or electromechanically. A microprocessor control computes and executes the appropriate motion of each joint to obtain a nozzle orientation having a desired bearing and azimuth within the monitor's hemisphere.

[0012] In the joint mechanism of this invention, the fundamental components of the joints and bearings are part of the waterway formed by the curved tube. The geometry of the joints is such that the water stream at each joint is always coaxial with that joint so as to eliminate any water-caused torque on the joint and drive. The geometry of the monitor is such that a full forwardly extending hemisphere ahead of a fire truck can be covered by a monitor mounted on a horizontal pipe on the front of the truck without requiring a 90° bend for vertical mounting. Alternatively, the

inventive monitor can cover an entire upwardly extending hemisphere centered on the truck if mounted vertically.

<u>Brief description of the drawings</u>

[0013] Fig. 1 is a horizontal section through a horizontally truck-mounted first embodiment of the monitor of this invention with the nozzle aimed straight ahead;

[0014] Fig. 2 is a view similar to Fig. 1 but showing the nozzle aimed to the left ;

[0015] Fig. 3 is a view similar to Fig. 1 but showing the nozzle aimed to the right;

[0016] Fig. 4 is a plan view of the monitor with the nozzle aimed up;

[0017] Fig. 5 is a view similar to Fig. 1 but showing an alternative embodiment of the invention;

[0018] Fig. 6 is a view similar to Fig. 3 but showing the alternative embodiment of Fig. 5;

[0019] Fig. 7 is a block diagram of an automatic control for the inventive monitor; and

[0020] Fig. 8 is a spatial diagram illustrating the geometry of the inventive monitor.

<u>Description of the preferred embodiments</u>

[0021] Fig. 1 shows a monitor 10 mounted on a horizontal pipe 12 e.g. on the front of a fire truck. The monitor 10 has a base section 14 terminating in a first joint 16 in which the midsection 18 of monitor 10 is mounted for swiveling movement about the horizontal

axis 20. At its other end, the midsection 18 terminates in a second joint 22 in which the nozzle-carrying exit section 24 is mounted for swiveling movement about an axis 26 preferably disposed at a 45° angle to the axis 20. A 45° angle produces a hemispheric coverage; greater or lesser angles produce greater or lesser coverage. The midsection 18 and the exit section 24 are preferably so curved that when the nozzle 28 is aimed straight ahead as shown in Fig. 1, the base section 14 and the nozzle 28 are coaxial.

[0022] When the nozzle 28 is aimed straight ahead, the net torque exerted by the water stream on the monitor 10 as a whole is essentially zero because the torque created by the clockwise 45° bends in the exit section 24 and the proximal end 30 of the midsection 18 are balanced by the 90° counterclockwise bend of the distal portion 32 of midsection 18. It will be noted that at the joints 16, 22 themselves, the water flow is coaxial with the joint, so that regardless of the position of the joint, the water flow through the joint does not create any torque on it.

[0023] The joints 16 and 22 may be swiveled by motors 34 and 36, respectively. These motors have relatively small drive gears 38 that engage the much larger gear 40 of the swiveling joint itself. Because of this size disparity, it is possible in the device of the invention to use a direct drive instead of the more cumbersome worm gear drive typical of the prior art. This in turn makes it practical to swivel the joints 16, 22 by hand, e.g. in case of a motor failure, through a hand wheel 42.

[0024] To prevent undesired movement of the monitor 10, the shafts 44 of drive gears 38 may be equipped with conventional

brakes 46 that prevent the shafts 44 from turning unless the motors 34, 36 are powered or the brake 46 is manually released. Alternatively, the motors 34, 36 may be computer-controlled servomotors that electrically maintain the joints 16, 22 in the desired positions. Dynamic braking may also be achieved by shorting the motor poles through a normally closed switch that can be opened for manual override.

[0025] Figs. 2 through 4 show the nozzle 28 aimed to the left, to the right, and to the observer, respectively. If the two limit positions of the axis 37 of nozzle 28 (which is at an acute angle to axis 26) as a result of the swiveling of joint 22 are coaxiality with axis 20 and perpendicularity thereto, Figs. 2-4 will show that the monitor of Fig. 1 is capable of aiming the nozzle 28 anywhere within a hemisphere centered on the monitor 10.

[0026] Figs. 5 and 6 illustrate an alternative embodiment of the invention, in which the midsection 18 forms a single 45° bend between the joint 16 and the joint 22, with the exit section 24 having the clockwise (in Fig. 5) 90° bend followed by a counterclockwise (in Fig. 5) 45° bend to the nozzle 28. Otherwise, however, the embodiment of Figs. 5 and 6 works in the same way as the embodiment of Figs. 1-4. It is, however, preferable from a torque point of view because the nozzle 28 in this embodiment is nearer to the joint 16 in the direction of the axis 20 than in the embodiment of Figs. 1-4.

[0027] It will be seen from Figs. 1 and 5 that the modular construction of the inventive device with 45° bends, 90° bends, and straight pieces/joints allows the inventive device to be arranged in

several different configurations to suit particular applications. In all of these configurations, however, turbulence is minimized by the gradual curvature of the water conduit and the unbroken smooth interior wall of the water conduit. The straight pieces such as 29 in Fig. 1 form a counterpart to a joint such as 22 to maintain the ability of axes 20 and 37 to become coaxial in the Fig. 1 position.

[0028] The novel geometry of the inventive monitor presents some control issues not encountered in the prior art. Specifically, for example, in a vertically mounted monitor, a transition of the nozzle 28 from a horizontal to a vertical orientation while remaining in the same vertical plane 50 (Fig. 8) requires a coordinated simultaneous rotation of both the joint 22 and the joint 16. Thus, in Fig. 8, if the home position of the nozzle 28 is coaxial to the intersection of horizontal plane 52 and vertical plane 50, a transition of the nozzle 28 in the vertical plane 50 from horizontal to vertical requires a simultaneous rotation of the joints 22 and 16 in accordance with the trigonometrically derived formulas

$$T = \arccos \{(1/\sin^2 M)*(\cos^2 M - \sin E)\} \qquad (1)$$

$$B = \arctan \{\sin T/[\cos M*(1+\cos T)]\} \qquad (2)$$

wherein E is a desired elevation angle above the horizontal plane 52; M is the inclination of the axis 26 of the joint 22 with respect to the axis 20; T is the required rotation angle of joint 22; and B is the required rotation angle of joint 16.

[0029] In order to aim the nozzle 28 at the elevation E in any vertical plane 54 other than the plane 50, the desired azimuth angle A is simply added to the rotation required by formula (2), so the

total rotation R of joint 16 is

$$R = B + A \tag{3}$$

[0030] For the simplest case in which $M = 45^\circ$ (and consequently sinM equals cosM), formula (1) reduces to

$$T = \arccos \{1 - (\sin E / \sin^2 M)\} \tag{4}$$

[0031] For elevation changes in 5° increments, formula (4) yields the following look-up table for a nozzle transition from horizontal to vertical in plane 50 of Fig. 8:

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Elevation (degrees)	Joint 22 (degrees)	Joint 16 (degrees)
0	0	0
5	34	24
10	49	33
15	61	40
20	72	46
25	81	50
30	90	55
35	98	59
40	107	62
45	114	66
50	122	69
55	130	72
60	137	74
65	144	77
70	152	80
75	159	82
80	166	85
85	173	87
90	180	90

TABLE I

[0032] It will be seen that the rotation of neither joint is linear, with the rotations for each 5^{o} interval being greatest near the horizontal and diminishing toward the vertical.

[0033] The positioning and tracking of the nozzle 28 may readily be accomplished automatically through the use of a microprocessor 56 (Fig.7). The inputs 58, 60 to the microprocessor 56 are the desired values, respectively, of elevation and azimuth. These may be generated manually, preferably digitally, by a keyboard or joystick. Alternatively, they may be generated by a computer program programmed to move the nozzle 28 in a desired predetermined pattern or in response to an operator's or sensor's instructions.

[0034] By means of a look-up table 61 such as Table I above, or by means of direct computation from formulas (1) through (4) above, the microprocessor 56 first computes at 62 a joint-22 position signal 64 that represents the rotational position of joint 22 which will produce the desired elevation, and outputs that signal to the servomotor 36. Based on the input 58 or the signal 64, the microprocessor 56 then computes at 63 the compensatory rotation of joint 16 that is necessary to maintain the nozzle 28 in the vertical home plane 50 at the chosen elevation. The resulting signal 66 is then added in adder 68 to the signal 60 representing the chosen azimuth to produce the joint-16 position signal 70 that is applied to servomotor 34. Position feedback signals 72, 74 from the servomotors 34, 36 may be used to correct any unintended rotation of the joints 22, 16 as a result of torque transients in the water stream or other causes.

[0035] The feedback signals 72, 74 may be generated in a variety of ways. For example, a potentiometer or other analog device, an optical encoder, or a Hall effect sensor or other pulse counter, may be used on either a motor or a joint.

[0036] The motors 34, 36 may of course be operated manually by a joystick or similar device. Because of the interrelationship of the rotations of joints 22 and 16, however, accurate manual handling of the monitor 10 with a joystick is likely to require skill and experience.

[0038] Another way of manually handling the joints 16, 22 in the absence of any motors (or handling motors by incremental-rotation pulsing) relies on a corollary of Table I. If the joint 10 is equipped e.g. with equidistant markings or detent notches around its circumference, the joint 22 can be equipped with corresponding non-equidistant notches or markings that are increasingly farther apart as nozzle 28 approaches the horizontal in Fig.8. The rotational increments between the markings are so calculated that a rotation of joint 22 from one of its non-equidistant marks to the next requires a compensating movement of joint 16 from one of its equidistant marks to the next. Thus, joint 16 may first be moved to point the nozzle 28 in a desired azimuth direction. Then, if the elevation is changed by moving joint 22 by e.g. three marks, joint 16 need merely also be moved three marks to maintain the nozzle 28 in the same azimuth direction.

[0039] It will be understood that the embodiments of the invention described herein are only illustrative, and that the

invention may be carried out in a variety of different ways without departing from the scope of the following claims.